8.0 BASELINE HUMAN HEALTH RISK ASSESSMENT SUMMARY

The ~~Baseline Human Health Risk Assessment (~~BHHRA~~)~~ presents an evaluation of risks to human health at the Portland Harbor Superfund Site. It is intended to provide an analysis of baseline risks and help determine the need for action at the Site, and to provide risk managers with an understanding of the actual and potential risks to human health posed by the ~~s~~Site and any uncertainties associated with the assessment.

Consistent with USEPA guidance (USEPA 1989), the BHHRA incorporates assumptions to provide a health protective assessment of risks associated with contaminants present at the Site. The risk assessment for Portland Harbor is a baseline risk assessment in that it evaluates human health risks and hazards associated with contamination in the absence of remedial actions or institutional controls. The BHHRA follows the approach that was documented in the Programmatic Work Plan (Integral~~ et al.~~, Windward, Kennedy/Jenks, Anchor, and GSI 2004) and subsequent interim documents. It also reflects numerous discussions and agreements on appropriate risk assessment techniques for the Site among interested parties, including the USEPA, ~~Oregon Department of Environmental Quality (~~DEQ~~)~~, ~~Oregon Department of Human Services (~~ODHS~~)~~, and Native American Tribes.

Potential exposure pathways, populations, and exposure assumptions were originally identified in the Programmatic Work Plan and in subsequent direction from USEPA. Additional assumptions for estimating the extent of exposure were provided in the Exposure Point Concentration Calculation Approach and Summary of Exposure Factors Technical Memorandum (Kennedy/Jenks ~~Consultants~~ 2006) and the Human Health Toxicity Values Interim Deliverable (Kennedy/Jenks ~~Consultants~~ 2004~~a~~). The BHHRA is based on USEPA (1989, 1991~~a~~, 2001~~b~~a, 2004c, 2005~~a~~c) and USEPA Region 10 (2000b) guidance, and is also consistent with DEQ guidance (DEQ 2000, 2010c).

The remainder of this section presents a summary of the methods used and results of the BHHRA, including the data evaluation, exposure assessment, toxicity assessment, risk characterization, uncertainty analysis, and conclusions. The complete BHHRA is presented in Appendix F to this RI report.

8.1 DATA EVALUATION

The sources of data available for use in the BHHRA are described in Section 2 of this RI ~~R~~report. The use and evaluation of those data for purposes of the BHHRA are described in Section 2 of Appendix F. Data from LWG and non-LWG sampling events were included in the SCRA database, a subset of which was used for the BHHRA. Only data that meet QA2Cat1 data quality objectives were used in the BHHRA. Data collected between RM 1.0, including Multnomah Channel and upstream to RM 12.2 were included in the risk assessment. Samples collected between RM 1.9 and RM 11.8 were considered to be within the Study Area, which was the focus of the BHHRA. The following summarizes the data used in the BHHRA by medium:

- **Beach Sediment:** Composite beach sediment samples that were collected from designated human use areas within the Study Area.
- **In-water Sediment:** In-water sediment (i.e., not beach sediment) samples that were collected from the top 30.5 cm in depth between the bank and the navigation channel.
- **Surface Water:** All Round 2 and Round 3 surface water data collected from the Study Area, as well as Multnomah Channel.
- **Groundwater Seep:** Data from Outfall 22B, which discharges in a potential human use area. However, samples collected from this outfall as part of a stormwater sampling event were excluded.
- **Fish Tissue:** Composite samples, both whole body and fillet with skin (fillet without skin samples were analyzed for mercury only), of target resident fish species (smallmouth bass, brown bullhead, black crappie, and common carp). Composite samples of adult Chinook salmon (whole body, fillet with skin, and fillet without skin), adult lamprey (whole body only), and sturgeon (fillet without skin only) were also included in for evaluation of consumption by tribal members.
- **Shellfish Tissue:** Composite samples of crayfish and clam tissue, depurated and undepurated.

Because of the large number of chemicals detected in environmental media, a risk-based screening approach was used to focus the risk assessment on those contaminants most likely to significantly contribute to the overall risk. Contaminants of potential concern (COPCs) were selected for quantitative evaluation in the BHHRA by comparing the SCRA analytical data to risk-based screening values. If the maximum detected concentration of a chemical exceeded its appropriate risk-based screening level, or if a risk-based screening level was not available, the contaminant was selected as a COPC.

8.2 EXPOSURE ASSESSMENT

The exposure assessment consists of three primary tasks:

- Characterization of the exposure setting. This step includes identifying the characteristics of populations that can influence their potential for exposure, including their location and activity patterns, current and future land use considerations, and the possible presence of any sensitive subpopulations.
- Identification of exposure pathways. Exposure pathways are identified for each population by which they may be exposed to chemicals originating from the site.

- Quantification of exposure. The magnitude, frequency, and duration of exposure for each pathway is determined. This step consists of the estimating of exposure point concentrations (EPCs) and calculation of chemical intakes.

8.2.1 Conceptual Site Model

The ~~conceptual site model (~~CSM~~)~~ describes potential contaminant sources, transport mechanisms, potentially exposed populations, exposures pathways, and routes of exposure. Currently or potentially exposed populations were identified based on consideration of both current and potential future uses of the Study Area, and include populations who may be exposed to contamination though a variety of activities. Exposure pathways are defined as the physical ways in which chemicals may enter the human body. A complete exposure pathway consists of the following four elements:

- A source of chemical release
- A release or transport mechanism (or media in cases involving media transfer)
- An exposure point (a point of potential human contact with the contaminated exposure medium)
- An exposure route (e.g., ingestion, dermal contact) at the exposure point.

If any of the above elements is missing, the pathway is considered incomplete and exposure does not occur. The relevant potential exposure pathways to human populations at the Study Area include:

- Incidental ingestion of and dermal contact with beach sediment
- Incidental ingestion of and dermal contact with in-water sediment
- Incidental ingestion of and dermal contact with surface water
- Incidental ingestion of and dermal contact with surface water from seeps
- Consumption of fish and shellfish
- Infant consumption of human milk.

8.2.2 Identification of Potentially~~-~~ Exposed Populations

The specific populations and exposure pathways evaluated in the BHHRA were as follows:

- Dockside workers~~—d~~Direct exposure via incidental ingestion and dermal contact with beach sediments~~.~~
- In-water workers~~—d~~Direct exposures to in-water sediment~~.~~
- Transients~~—d~~Direct exposure to beach sediment, surface water for bathing and drinking water scenarios, and groundwater seeps~~.~~

- Recreational beach users—~~d~~Direct exposure to beach sediment and surface water while for swimming~~.~~
- Tribal fishers—~~d~~Direct exposure to beach or in-water sediments, and consumption of migratory and resident fish~~.~~
- Recreational and subsistence fishers—~~d~~Direct exposure to beach or in-water sediments, consumption of resident fish, and consumption of shellfish~~.~~
- Divers—~~d~~Direct exposure to in-water sediment and surface water~~.~~
- Domestic water user—~~d~~Direct exposure to untreated surface water potentially used as a drinking water source in the future~~.~~
- Infant consumption of human breast milk—~~e~~Exposure to certain persistent and bioaccumulative contaminants (PCBs, DDx compounds, dioxins and furans, and PBDEs) via nursing infants of dockside and in-water workers, divers, and recreational, subsistence, and tribal fishers.

Exposures were evaluated on a Study Area-wide basis, as well as on more localized spatial scales as appropriate for each exposure scenario. Exposure to beach sediment was assessed per beach, and exposure to groundwater seeps was assessed per seep. Exposure to in-water sediment, surface water, and fish and shellfish tissue was assessed on both localized and Study Area-wide scales. Except where specifically noted, the exposure assumptions used in the BHHRA were applied uniformly to all of the Study Area, and may or may not be applicable at specific locations within the Study Area depending on factors not specifically addressed in the BHHRA.

Consistent with USEPA policy, the exposure assessment evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. In addition, estimates of ~~central tendency (~~CT~~)~~, which are intended to represent average exposures, were also evaluated. Assumptions about each population were used to select exposure parameters to calculate the pathway-specific chemical intakes. As site-specific values are not available to describe potential exposures for each population~~s~~ and pathway~~s~~, default values representative of the larger U.S. population were used. Where default values are not available, best professional judgment was used based on likely activity patterns.

8.2.3 Exposure Point Concentrations

~~Exposure point concentrations (~~EPCs~~)~~ were calculated to represent the average concentration contacted over the duration of the exposure. The average is used to represent "a reasonable estimate of the concentration likely to be contacted over time" (USEPA 1989). USEPA guidance (USEPA 1989, 1992) recommends that the 95 percent upper confidence limit (UCL) on the arithmetic mean should be used to represent the average because of the uncertainty associated with estimating the true average concentration at a site. The maximum reported concentration was used in instances where there were insufficient data to calculate a UCL, or the calculated UCL was greater than the maximum reported value. The simple mean was used as the EPC in sediment and surface water for the CT evaluations.

8.2.4 Estimation of Chemical Intakes

The amount of each chemical incorporated into the body is defined as the dose and is expressed in units of milligrams per kilogram per day (mg/kg-day). The dose is calculated differently when evaluating carcinogenic effects than when evaluating noncarcinogenic effects.

For non-occupational scenarios where exposures to children are considered likely, exposures to both adult and child were evaluated. Children often exhibit behavior such as outdoor play activities and greater hand-to-mouth contact that can result in greater exposure than for a typical adult. In addition, children ~~also~~ have a lower overall body weight relative to the predicted intake. As cancer risks are averaged over a lifetime, they are directly proportional to the exposure duration. Accordingly, a combined exposure from childhood through adult years was evaluated where appropriate, to account for the increased relative exposure and susceptibility associated with childhood exposures.

In general, Superfund exposure assessments assess RME by using a combination of 90^{th} or 95^{th} percentile values for contact rate, exposure frequency, and duration, and 50^{th} percentile values for other variables. CT estimates are done using average or median values for all variables.

For example, a range of fish consumption rates was evaluated using information from studies conducted in the Willamette and Columbia ~~R~~river basins, as well as from data representing the general U.S. population. A consumption rate of 17.5 g/day (approximately ~~2 eight ounce~~two 8-oz meals per month) was considered representative of a CT value for recreational fishers, 49 g/day and 142 g/day per day (approximately ~~7~~seven and ~~19 eight ounce~~nineteen 8-oz meals per month) were selected as the RME value representing the higher-end consumption practices of recreational fishers and for high levels of fish consuming, or subsistence, fishers, respectively.

The rates of 17.5 g/day and 142 g/day represent the 90^{th} and 99^{th} percentiles, respectively, of per capita consumption of uncooked freshwater/estuarine finfish and shellfish by individuals (consumers and non-consumers) 18 or older, as reported in the Continuing Survey of Food Intakes by Individuals ~~(CSFII)~~ and described in USEPA's Estimated Per Capita Fish Consumption in the United States (USEPA ~~2002b).~~2002~~f~~d). The consumption rate of 49 g/day is from a creel study conducted in the Columbia Slough (Adolfson 1996), and represents the 95 percent ~~upper confidence limit~~UCL on the mean, where 50 percent of the mass of the total fish is consumed. Tribal consumption of a mixed diet consisting of both resident and anadromous fish was evaluated using a consumption rate of 175 g/day (approximately ~~23 eight~~ twenty-three 8-oz meals per month), representing the 95^{th} percentile of consumption rates from the ~~Columbia River Inter-Tribal Fish Commission (~~CRITFC~~,~~ (1994) survey.

8.3 TOXICITY ASSESSMENT

The toxicity assessment is composed of two steps: ~~(~~1) hazard identification and ~~(~~2) dose-response assessment. Hazard identification is a determination of whether exposure to a chemical may result in an adverse health effect in humans, consisting of characterizing the nature of the effect and the strength of the evidence that the chemical will cause the observed effect. The dose-response assessment characterizes the relationship between the dose and the incidence and/or severity of the adverse health effect. For risk assessment purposes, chemicals are generally separated into categories based on whether a chemical exhibits carcinogenic or noncarcinogenic health effects. As appropriate, a chemical may be evaluated separately for both effects. Noncancer effects are evaluated using a reference dose (RfD). The RfD, expressed in units of mg of substance/kg body weight-day (mg/kg-day) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population, including sensitive subgroups, that is likely to be without an appreciable risk of adverse effects resulting from a lifetime exposure. RfDs are based on the concept that exposures less than the critical value are without adverse health effects. Carcinogenic effects are assessed using the cancer slope factor, which is typically expressed in units of per mg of substance/kg body weight-day ~~(~~[(mg/kg-day)$^{-1}$]. The slope factor represents an upper bound estimate on the increased cancer risk. Slope factors are generally accompanied by a weight of evidence descriptor, which expresses the confidence as to whether a specific chemical is known or suspected to cause cancer in humans.

The recommended hierarchy of toxicity values for use in Superfund risk assessment is as follows (USEPA 2003b):

- Tier 1 – USEPA's Integrated Risk Information System (IRIS) database (USEPA 2010~~b~~a).
- Tier 2 ~~–~~– USEPA's Provisional Peer Reviewed Toxicity Values ~~(PPRTVs)~~ derived for use in the Superfund Program when values are not available in IRIS.
- Tier 3 ~~–~~– USEPA and non-USEPA sources of toxicity information, with priority given to those sources of information that are the most current, transparent, and publicly available, and which have been peer reviewed. Tier 3 sources may include, but are not be limited to, the following sources:
  - The California Environmental Protection Agency ~~(Cal EPA)~~ Toxicity Criteria Database (Cal EPA 2008)~~.~~
  - ATSDR Minimal Risk Levels~~.~~
  - USEPA's Health Effects Assessment Summary Tables ~~(HEAST)~~.

8.4 RISK CHARACTERIZATION

Risk characterization integrates the information from the exposure assessment and toxicity assessment, using a combination of qualitative and quantitative information.

Risk characterization is performed separately for carcinogenic and noncarcinogenic effects. Carcinogenic risk is expressed as the incremental increased probability that an individual will develop cancer over a lifetime as a result of exposure to a potential carcinogen. Noncarcinogenic hazards are evaluated by comparing an estimated exposure level, or dose, with the RfD that is without appreciable risk of adverse health effects

8.4.1 Risk Characterization Methodology

Noncancer effects are addressed by comparing the estimated dose, as defined by the chronic daily intake, to the corresponding RfD to yield an ~~hazard quotient (~~HQ~~)~~. HQs for multiple chemicals are summed across all relevant exposure pathways to calculate the cumulative hazard indices (HIs). Although an HI provides an overall indication of the potential for noncancer hazards, dose additivity is most appropriately applied to chemicals that induce the same effect via the same mechanism of action. When the HI is greater than 1 due to the sum of several HQs of similar value, it is appropriate to segregate the chemical-specific HQs by toxicological effect and mechanism of action. When either the cumulative or the effect-specific HI is less than 1, adverse health effects associated with the exposures are considered unlikely.

Potential cancer risks were assessed by multiplying the estimated dose by the appropriate cancer slope factor. This calculated risk is expressed as the probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen, and is a conservative, health-protective estimate of the incremental probability of excess individual lifetime cancer risk.

Response actions under CERCLA are generally warranted when the baseline risk assessment indicates a cumulative risk under either current or future exposure is greater than the upper end of the acceptable risk range of $1\times\cancel{x}10^{-4}$ to $1\times\cancel{x}10^{-6}$, or when the HI is greater than 1. Accordingly, risk and hazard estimates are generally presented in terms of whether they are greater than $1\times\cancel{x}10^{-4}$ or greater than 1, respectively.

8.4.2 Risk Characterization Results

The ranges of estimated potential risks resulting from the different exposure scenarios are summarized in Table 8.4-1. A summary of the risk characterization results is presented by exposure scenario in the following sections.

8.4.3 Dockside Workers

Risks to dockside workers were estimated separately for each of the eight beaches designated as a potential dockside worker use areas. The estimated cancer risks are less than $1\times\cancel{x}10^{-4}$ at all beach areas, and the HIs are less than 1 for adults and infants.

8.4.4 In-Water Workers

In-water sediment exposure by in-water workers was evaluated in half-mile increments along each side of the river. The estimated CT and RME cancer risks are less than

1×~~x~~10^{-4} at all ~~RM~~river mile segments, and the RME HIs for adults are less than 1 at all locations. The HI for infants at RM 7W is 2 due to dioxins and furans.

8.4.5 Transients

Risks to transients were estimated separately for each beach designated as a potential transient use area, as well as for the use of surface water as a source of drinking water and for bathing. Year-round exposure to surface water was evaluated for four individual transect stations, Willamette Cove, Multnomah Channel, and for four transects grouped together to represent Study Area-wide exposure. The CT and RME risk estimates for beach sediment are less than 1×~~x~~10^{-4} for all locations, and the HIs are less than 1. Estimated CT and RME cancer risks associated with surface water exposures, including surface water from a groundwater seep at Outfall 22, are less than 1×~~x~~10^{-4} at all locations, and the HIs are less than 1.

8.4.6 Divers

Commercial divers were evaluated for exposure to surface water and in-water sediment, assuming the diver was wearing either a wet or a dry suit. In-water sediment exposure by divers was evaluated in half-mile exposure areas for each side of the river, and on a Study Area-wide basis. Risks associated with exposure to surface water were evaluated for four individual transect stations, and at single-point sampling stations grouped together in one-half mile increments per side of river.

The estimated CT and RME cancer risks associated with exposure to in-water sediments by divers wearing wet suits are less than 1×~~x~~10^{-4} at all half-mile river segments as well as for Study Area-wide exposure, and the HIs are also less than 1 for adults. The HI for indirect exposure to infants of adult divers is 2 at RM 8.5W for the RME evaluation, due to PCBs. The estimated CT and RME cancer risks associated with exposure to surface water are less than 1×~~x~~10^{-4} for all half-mile river segments, and the HIs are less than 1.

The estimated RME cancer risk associated with exposure to in-water sediments and surface water by divers wearing dry suits is less than 1×~~x~~10^{-4} at all half-mile river segments and for Study Area-wide exposure, and the HI is also less than 1 for adults and indirect exposures to infants via breastfeeding.

8.4.7 Recreational Beach Users

Risks associated with exposure to beach sediment were evaluated separately for each beach designated as a potential recreational use area, and exposure to surface water was evaluated using data collected from three transect locations and three single-point locations at Cathedral Park, Willamette Cove, and Swan Island Lagoon. Estimated CT and RME cancer risks associated with exposure to beach sediments and surface water are less than 1×~~x~~10^{-4} at all recreational beach areas, and the HIs are also less than 1. Indirect exposures to infants via breastfeeding were not evaluated.

8.4.8 Recreational/Subsistence Fishers

Recreational and subsistence fishers were evaluated assuming direct exposure to contaminants in sediment and via consumption of fish and shellfish. Exposures associated with beach sediment were assessed at individual beaches designated as potential transient or recreational use areas~~,~~; in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Sediment exposures were further assessed as CT and RME evaluations and assuming either a low- or a high-frequency rate of fishing.

Estimated CT and RME cancer risks associated with both low- and high-frequency fishing exposures to either beach or in-water sediments are less than 1×~~x~~10^{-4} at all areas evaluated. HIs associated with adult exposures to beach sediment are less than 1 at all locations evaluated. The RME HI associated with adult exposures to in-water sediment is greater than 1 at RM 7W for high-frequency fishing; HIs for all other locations and fishing exposures are less than 1. The RME HI associated with indirect exposures of in-water sediment contamination to infants via breastfeeding is greater than 1 at RM 7W and ~~RM~~ 8.5W. Indirect exposure to contaminants in beach sediment to infants was not evaluated.

Consumption of resident fish species was evaluated on a river mile basis using smallmouth bass data as a surrogate for all fish consumed. Consumption of fish was also evaluated over the entire Study Area assuming a diet consisting of equal proportions of common carp, brown bullhead, back crappie, and smallmouth bass. Consumption on a river mile basis was evaluated only for recreational fishers~~,~~; consumption averaged over the entire Study Area was evaluated for both recreational and subsistence fishers. With the exception of RM 5, RME risk estimates on a river mile basis are all greater than 1×~~x~~10^{-4}. CT estimates are greater than 1×~~x~~10^{-4} at RM 7, Swan Island Lagoon, and RM 11. River miles exhibiting the highest estimated RME risks are: RM 2 (2×~~x~~10^{-4}), RM 4 (3×~~x~~10^{-4}), RM 7 (6×~~x~~10^{-4}), Swan Island Lagoon (6×~~x~~10^{-4}), RM 9 (2×~~x~~10^{-4}), and RM 11 (1×~~x~~10^{-3}). Study Area-wide RME risks for recreational and subsistence fishers are 4~~x~~×10^{-3} and 1×~~x~~10^{-2}, respectively; the Study Area-wide CT estimate for recreational fishers is 1×~~x~~10^{-3}.

RME and CT HIs are greater than 1 at all river miles. River miles exhibiting the highest estimated HIs are RM 4, RM 7, Swan Island Lagoon, and RM 11. Study Area-wide RME HIs for recreational and subsistence fishers are 300 and 1,000, respectively~~,~~; the CT estimate for recreational fishers is 100.

RME HIs associated with indirect exposure to infants via breastfeeding range from 30 to 1,000, and CT estimates range from 10 to 500, when assessed on a river mile scale. Study Area-wide, the HIs for recreational fishers are 2,000 and 4,000 for the CT and RME estimates, respectively, and the RME HI for subsistence fishers is 10,000. River miles exhibiting the greatest RME HIs are: RM 2 (200), RM 4 (200), RM 7 (200), Swan Island Lagoon (600), and RM 11 (1,000). The majority of the hazard ~~estimates~~estimate is attributable to PCBs.

EPCs on a river mile scale use data from smallmouth bass to represent contaminant concentrations in all resident fish species, and consumption was assumed to consist primarily of just the fillet rather than other parts of the fish. However, an evaluation of the data collected from Portland Harbor indicates that PCB concentrations in whole body smallmouth bass are typically an order of magnitude greater than those measured in just the fillet. By contrast, in common carp and brown bullhead, the observed ratio of whole body-to-fillet PCB concentrations is less than noted in smallmouth bass, meaning that given the same overall PCB concentration in whole body fish, the PCB concentration in smallmouth bass fillet tissue will be less than for carp and bullhead. These differences are reflected in the exposure concentrations such that the use of fillet smallmouth bass data on a river mile scale resulted in a greater relative reduction of PCB concentration than would be seen if fillet data from common carp and brown bullhead were included. A diet that consists of some portion of carp and bullhead could result in relatively greater intake of PCBs, and the associated risk and hazard would be correspondingly greater as well. In addition, at least some of the fishers in the Portland Harbor area consume more than just the fillet. Consumption of other portions of the fish in addition to the fillet can result in greater relative exposure to PCBs and other persistent bioaccumulative chemicals and thus, greater relative risks.

~~8.4.8.1 Consumption of Shellfish~~

Commented [A1]: **Integral:** This 4th level header does not seem necessary and others would need to be added to this section if retained (e.g., Consumption of Fish).

Risks from consumption of clams and crayfish were evaluated for subsistence fishers. Estimated RME cancer risks associated consumption of undepurated clams by subsistence fishers are greater than 1× ~~x~~ 10^{-4} at 10 of the 22 river mile sections evaluated. The estimated risk Study Area-wide is 4× ~~x~~ 10^{-4}. Carcinogenic PAHs pose the highest risks at RM~~s~~ 5W and ~~RM~~ 6W, while PCBs pose the highest risks in Swan Island Lagoon and RM 11. Carcinogenic PAHs and PCBs pose the highest risks on a Study Area-wide basis. Estimated CT cancer risks are all less than 1× ~~x~~ 10^{-4}. Risks based on depurated clams were estimated at RM 1E, ~~RM~~ 2W, ~~RM~~ 10W, ~~RM~~ 11E, and ~~RM~~ 12E, and none of the estimated CT or RME cancer risks are greater than 1× ~~x~~ 10^{-4}. The estimated RME HIs associated consumption of undepurated clams by subsistence fishers are greater than 1 at 20 of the 22 river mile sections evaluated, as well as when evaluated on a Study area-wide basis. RME HIs associated with indirect exposure to infants via breastfeeding are greater than 1 at each river mile evaluated.

The estimated RME cancer risks associated consumption of crayfish by subsistence fishers are greater than 1× ~~x~~ 10^{-4} at RM 7W and RM 11E, as well as on Study Area-wide basis. All estimated CT cancer risks are less than 1× ~~x~~ 10^{-4}.

The estimated RME HIs associated consumption of crayfish by subsistence fishers are greater than 1 at ~~seven~~7 of the 32 individual stations~~,~~; the estimated HI Study Area-wide is 10. RME HIs associated with indirect exposure to infants via breastfeeding are greater than 1 at 23 of the 32 stations evaluated~~,~~; the HI is 200 when evaluated Study Area-wide.

8.4.9 Tribal Fishers

Exposures to tribal fishers were evaluated assuming direct contact with contaminants in sediment and via consumption of fish. Exposures associated with beach sediment were assessed at individual beaches, and in-water sediment exposures were evaluated on a one-half river mile basis per side of the river and as an averaged, Study Area-wide evaluation. Fish consumption was evaluated assuming a multi-species diet consisting of anadromous and resident fish species, and fishing was evaluated on a Study Area-wide basis.

The estimated CT and RME cancer risks associated with direct contact to beach sediment is less than 1×~~x~~10^{-4} at all beaches evaluated. RME cancer risk associated with exposure to in-water sediment is greater than 1×~~x~~10^{-4} at RM 6W and ~~RM~~ 7W. With the exception of in-water sediment exposure at RM 7W, the estimated HIs are less than ~~one~~1 at all beach and in-water locations evaluated. Noncancer CT and RME HIs associated with indirect exposure to infants via breastfeeding were evaluated assuming maternal exposure to in-water sediment. The estimated RME HI is greater than 1 at RM 7W, ~~RM~~ 8.5, and ~~RM~~ 11E.

The estimated RME cancer risk for tribal consumption of fish is 2×~~x~~10^{-2} assuming whole body consumption, and 1×~~x~~10^{-2} assuming consumption of fillets only. RME HI associated with childhood consumption of whole body fish is 800, and is 600 assuming consumption of fillets only. RME HI associated with indirect exposure of tribal infants via breastfeeding assuming maternal consumption of whole body fish is 9,000, and is 8,000 assuming maternal fillet-only consumption.

8.4.10 Domestic Water Use

Use of surface water as a source of household water for drinking and other domestic uses was evaluated using data from five transect and 15 single point sampling locations, as well as averaged over a Study Area-wide basis. The estimated cancer risk for combined child and adult exposures is greater than 1×~~x~~10^{-4} at RM 6W.

The estimated HIs based on childhood exposure are equal to or greater than 1 at several sampling locations: W005 (1) at RM 4, W023 (1) at RM 11, W027 (2) near the mouth of Multnomah Channel, and W035 (2) in Swan Island Lagoon. In all instances, ~~MCPP~~2-(4-chloro-2-methylphenoxy)propanoic acid is the primary contributor to the estimated hazard.

8.4.11 Cumulative Risk Estimates

Cumulative risk and hazard estimates were calculated for those populations where concurrent exposure to more than one media was assumed to be plausible. Recreational/subsistence and tribal fishers were further ev~~—~~aluated on the basis of whether they were assumed to fish predominately from the shore or from a boat. Populations for which concurrent exposure to more than one medi~~a~~um was considered ~~for~~ are as follows:

- Transients: Beach sediment, surface water
- Divers: In-water sediment, surface water
- Recreational beach users: Beach sediment, surface water
- Recreational fishers (beach): Beach sediment, fish tissue (fillet)
- Recreational fishers (boat): In-water sediment, fish tissue (fillet)
- Subsistence fishers (beach): Beach sediment, fish tissue (fillet), shellfish tissue
- Subsistence fishers (boat): In-water sediment, fish tissue (fillet), shellfish tissue
- Tribal fishers (beach): Beach sediment, fish tissue (fillet and whole body)
- Tribal fishers (boat): In-water sediment, fish tissue (fillet and whole body).

Cumulative risk estimates were generally calculated for each one-half river mile per side of the river, and the risk estimates for specific media appropriate to each one-half mile segment were used to calculate the total risk or hazard. For example, cumulative risks for recreational fishers who fish from a boat and consume smallmouth bass would include the risks associated with exposure to in-water sediment at the specific half-mile and smallmouth bass from the larger river mile assessment. Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps. PCBs are the primary contributor to risk from fish consumption harbor wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

8.4.12 Identification of Contaminants Potentially Posing Unacceptable Risks

Contaminants were identified as potentially posing unacceptable risks if they resulted in a cancer risk greater than $1 \times ~~x~~ 10^{-6}$ or a HQ greater than 1 under any of the exposure scenarios for any of the EPCs evaluated in the BHHRA, regardless of the uncertainties. There were 33 contaminants identified as potentially posing unacceptable risks for the exposure scenarios listed above. Only a subset of these contaminants ~~were~~was associated with cancer risks exceeding $1 \times ~~x~~ 10^{-4}$ or HQs exceeding 1, and an even smaller number of contaminants contributed to most of the relative percentage of total risk. In some cases, the contaminants were identified as potentially posing unacceptable risks based only on the highest ingestion rate, a single exposure point, and/or the maximum detected concentration. Four of the contaminants (alpha-, beta-, and gamma-~~hexachlorocyclohexane~~HCH and heptachlor) were identified as potentially posing unacceptable risks on the basis of N-qualified data only. The use of an "N" qualifier indicates that the identity of the analyte is not definitive. These four chemicals are not recommended for further evaluation of potential risks to human health. The remaining 29 contaminants identified as potentially posing unacceptable risks to human health are evaluated further in the Human Health Risk Management Recommendations document. These contaminants are presented in Table 8.4-2.

8.5 UNCERTAINTY ANALYSIS

The presence of uncertainty is inherent in the risk assessment process, and USEPA policy calls for numerical risk estimates to always be accompanied by descriptive information regarding the uncertainties of each step in the risk assessment to ensure an objective and balanced characterization of the true risks and hazards. The term "uncertainty" is often used in risk assessment to describe what are, in reality, two conceptually different terms: uncertainty and variability. Uncertainty can be described as the lack of a precise knowledge resulting in a fundamental data gap. Variability describes the natural heterogeneity of a population. Uncertainty can sometimes be reduced or eliminated through further measurements or study. By contrast, variability is inherent in what is being observed. Although variability can be better understood, it cannot be reduced through further measurement or study, although it may be more precisely defined. However, the additional cost of further data collection may become disproportional to the reduction in uncertainty.

The risks and hazards presented are consistent with USEPA's stated goal of RME representing the high end of the possible risk distribution, which is generally considered to be greater than the 90th percentile. However, these estimates are based on numerous and often conservative assumptions and, in the absence of definitive information, assumptions are used to ensure that actual sites risks are not underestimated. The cumulative effect of these assumptions can result in an analysis with an overall conservativeness greater than the individual components. Accordingly, it is important to note that the risks presented here are based on numerous conservative assumptions in order to be protective of human health and to ensure that the risks presented here are more likely to be overestimated rather than underestimated. A detailed analysis of the uncertainties associated with the BHHRA is found in Section 6 of Appendix F.

Exposure Parameters for Fish and Shellfish Consumption Scenarios. Site-specific information regarding fish consumption is not available for Portland Harbor prior to its listing as a Superfund site. In the absence of site-specific data, fish consumption data representative from several sources were considered and selected as being representative of the general population of the greater Portland area, as well as that portion of the population that actively fishes the ~~L~~lower Willamette and utilizes fish from the river as a partial source of food.

The rates presented in the ~~CSFII study~~Continuing Survey of Food Intakes by Individuals described in Section 8.2.4 represent per capita consumption rates rather than true long-term averaged consumption rates. In addition, the large range between the percentile values is indicative of substantial variability in the underlying data. In addition to the consumption rates, uncertainty also exists with respect to the relative percentage of the diet of obtained from the Study Area or within individual exposure areas versus other nearby sources of fish, and the degree to which different methods of preparation and cooking may reduce concentrations of persistent lipophilic contaminants.

Using the Maximum Concentration to Represent Exposure. In cases when there were fewer than five samples with a detected concentration for a given analyte for a given exposure area, the sample size was not sufficient to calculate a representative 95 percent UCL on the mean, so the maximum concentration detected was used as the EPC. Data sets with fewer than 10 samples generally provide poor estimates of the mean concentration, defined as a large difference between the sample mean and the 95 percent UCL. In general, the UCL approaches the true mean as more samples are included in the calculation of the exposure concentration.

Regional Tissue Concentrations. PCBs and dioxins/furans have been detected in fish tissue collected in the Willamette and Columbia rivers, outside of the Study Area. In the Columbia River Basin Fish Contaminant Survey, the basin-wide average concentrations of total PCBs in resident fish ranged from 0.032 to 0.173 parts per million (ppm) for whole body samples and from 0.033 to 0.190 ppm for fillet with skin samples (USEPA 2002e~~a~~). In the middle Willamette River (RM 26.5 to 72), the average concentrations of total PCBs in resident fish ranged from 0.086 to 0.146 ppm for whole body samples and from 0.026 to 0.071 ppm for fillet with skin samples (EVS 2000). The regional tissue concentrations may be associated with unacceptable risks from fish consumption, especially at higher consumption rates. However, these regional concentrations are lower than the concentrations detected in the Study Area, where average concentrations ranged from 0.16 to 2.8 ppm in whole body samples and from 0.17 to 2.5 ppm in fillet with skin samples (for PCBs as total congeners). The fish species included in the studies were different than those collected within the Study Area, so the concentrations may not be directly comparable. Sources contributing to the PCBs and dioxins/furans detected in fish collected outside of the Study Area are unknown and may not be relevant to the Study Area.

8.6 SUMMARY AND CONCLUSIONS

The following presents the major findings of the BHHRA[1]:

- Risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment, surface water, or seeps. Risks and hazards from fish and shellfish consumption exceed the USEPA point of departure for cancer risk of 1× ~~x~~ 10^{-4} and target HI of 1 when evaluated on a harbor-wide basis, and when evaluated on the smaller spatial scale by river mile.

[1] However, the identification of the contaminants presenting the most significant risk in various areas of the site consistent with USEPA risk assessment guidance is not intended to suggest that other contaminants in those areas and at the site generally do not also present potentially unacceptable risk.

- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4×~~x~~ 10^{-3} and 1×~~x~~ 10^{-2} for recreational and subsistence fishers, respectively. Evaluated on a river mile scale, it is only at RM 5, where the estimated RME risk for recreational fishers is 9×~~x~~ 10^{-5}, that the risk from consumption of resident fish is less than 1×~~x~~ 10^{-4}. River miles associated with the highest estimated risk estimates are RM 4, ~~RM~~ 7, ~~RM~~ 11, and in Swan Island Lagoon. Evaluated harbor-wide and assuming a diet that consists of migratory fish in addition to resident fish species, the estimated RME cancer risk for tribal consumers is 1×~~x~~ 10^{-2} assuming fillet-only consumption, and 2×~~x~~ 10^{-2} assuming whole body consumption.

- Noncancer hazard estimates for consumption of resident fish species are greater than 1 at all river miles. Evaluated harbor wide, the estimated RME HI is 300 and 1,000 for recreational and subsistence fisher, respectively. The highest hazard estimates are at RM 4, ~~RM~~ 7, ~~RM~~ 11, and in Swan Island Lagoon. The highest noncancer hazards are associated with nursing infants of mothers who consume resident fish from Portland Harbor. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME hazard for tribal consumers of migratory and resident fish is 600 assuming fillet-only consumption, and 800 assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers who consume fish are 8,000 and 9,000 respectively, assuming maternal consumption of fillet or whole-body fish.

- PCBs are the primary contributor to risk from fish consumption harbor wide. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall risk and hazard estimates. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The largest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from Portland Harbor. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it not clear to what degree contamination in Portland Harbor contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific disease, and the cancer estimates represent upper-bound values, and the USEPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.